The Dynamics of the Transfer and Renewal of Patents

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Abstract

This paper explores new data on the transfer and renewal of U.S. patents and interprets this new evidence using a theoretical model of patent transfers and renewal. We find that the proportion of transferred patents is large and differs across technology fields and especially types of patentees. We also find that the probability of a patent being traded depends on a number of factors–the age of the patent, the number of citations received by a given age, the patent generality, and whether the patent has been previously traded or not–. These findings are consistent with the predictions of a model of patent transfers and renewal with gains from trade and costs of technology adoption.

1 Introduction

There is an extensive work in the empirical patent literature[1]; the main contribution of this paper is that it makes use of data on the transfer of the ownership of patents. The United States Patent and Trademark Office (USPTO) registers the transfer of patents in the form of assignments, which acknowledge the transfer by a party of the rights, title and interest in a patent or bundle of patents. As we show here, the market for patents is large. For instance, 13.5% of all granted patents are traded at least once over their life cycle and this rate is higher when weighted by patent citations received. In our study, we make use of all these transferred

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[1] There exists a very extensive empirical body of work in economics using patent data. Schmookler [44], Scherer [45], Griliches [20], Pakes and Schankerman [37], Schankerman and Pakes [42], Pakes [36], Tratjenberg [49], Jaffe, Henderson and Tratjenberg [25], Putnam [40], Lanjouw [30], Schankerman [43] Harhoff, Narin, Scherer and Vopel [23], Lanjouw and Schankerman [31], Hall, Jaffe and Tratjenberg [22], etc.

titles and link this information to the basic patent data that others have used (e.g., renewals, patent citations received, generality, technology fields, patentees).[2] The objective of this paper is to describe the features of the new data set and present stylized facts that can provide both new evidence about the diffusion of technology and guidance in the assessment of models of intellectual property transfer.[3]

To understand the empirical regularities we present, we use a model of patent transfers and renewal (Serrano [46]). The starting point of our theory is Pakes and Schankerman [37] and Schankerman and Pakes [42]. They examine the problem of a patent owner deciding in each time period whether or not to pay a renewal fee, and thereby extend the life of a patent, in a context with heterogeneity in the economic value of inventions. The contribution of our theory is to introduce the possibility of arrival of opportunities for surplus-enhancing transfer, which may lead to alternative potential owners having greater valuation for a patent than the current owner. But to transfer a patent to a new owner involves a cost of technology adoption to be incurred by the buyer. Our model illustrates that the presence of both gains from trade and costs of technology adoption not only determine the proportion of traded patents, but also whether their characteristics differ from the untraded ones. For instance, we find that the probability of patents being traded increases with gains from trade and patent revenue while decreasing with costs of technology adoption and patent age. Moreover, previously traded patents are more likely to be traded and renewed than untraded ones.

To parallel our focus in the theory, our empirical work focuses on three aspects of the transfer and renewal of patents. First, we identify six types of distinct patentees and examine their rates of transfer and renewal. Second, we study the variation of the rates of transfer and renewal across technology fields as well as the relative importance of small patentees versus their larger counterparts in the rates of transfer for each technology field. Third, we analyze the impact of patent characteristics such as patent citations received, generality, and age in the dynamics of the transfer and renewal of patents.

The aspects of the data we explore are important for understanding the process and the benefits of the transfer of technology. Because the ability to commercialize inventions–and consequently the gains from trade–could differ for different firms, we must consider that the rates of transfer can vary across type of patentees. As a result, we classify patents into six types of patentees (individual private inventor patents, unassigned patents as of their grant

[2] Technology fields, patent citations received, patentees (i.e., patent owner/assignee as of the grant date of a patent) and generality information was obtained from the NBER Patent data set (Hall, Jaffe and Tratjenberg [22]). The measure of generality of patent i is $Generality_i = 1 - \sum_j^{n_i} s_{ij}^2$, where s_{ij} denotes the percentage of citations received by patent i that belong to patent subclass j, out of n_i patent classes. The patent renewal data is based on information from the USPTO Official Gazette as collected in the USPTO Patent BIB data base as of December 31, 2002.

[3] The benefits of acquiring a patent rather than obtaining a license may be to reduce potential hold up problems since patent ownership offers a higher degree of residual control rights than a license does (Grossman and Hart [21]).

date [owned by their inventors]; small, medium and large innovators; and government agencies). We define the size of innovators based on the number of patents granted in a given year.[4] We find substantial differences in the rates of transfer across the types of patentees, with individual private inventors and small innovators having the largest rates of transfer. These findings will help us learn for whom the benefits of patent trading are most likely to be important.

Second, since costs of technology adoption and the arrival of opportunities for surplus-enhancing transfer could differ across technology fields, we look at the rates of transfer for various technology fields. We have divided technology into six fields (chemical, computer and communication, drugs and medical, electricity and electronics, mechanical, and other). The findings reveal some differences in the rates of transfer, with the drug and medical field having the highest rates. It is possible that part of these differences exist because the benefits from specialization varie across technology fields. As a result, we also examine the differences in the rates of transfer of type of patentees for separate technology fields. We then find substantial differences between the rates of transfer of small innovators and their larger counterparts across technology fields. In addition, the technology fields with the largest difference do not necessarily correspond to the ones with the highest rates of transfer. For instance, small and large innovators in the computer and communications technology field transfer respectively 23.9% and 7.9% of their patents; meanwhile, their rates of transfer in the chemical field are 17.25 and 12.5% respectively. However, while 14.9% of chemical patents are traded, the rate of transfer is just 12.9% in computer and communications. This evidence will allow us to learn about the variation of costs of technology adoption, the arrival for surplus-enhancing transfer and the benefits from specialization across technology fields.

Third, because the rates of transfer and renewal could also depend on patent characteristics such as age, revenue, and the broadness of the patent, we study the impact of these elements as measured by number of years since the patent grant date, the total number of patent citations received by a given age, and the generality of the patent. The empirical analysis reveals that the probability of a patent being traded indeed depends on a number of factors: the age of the patent, the number of citations received by a given age, the patent generality, as well as whether or not the patent has been previously traded and if so, the number of years since the last trade. These facts provide some evidence on how to compare traded and untraded patents, the importance of traded patents and the life cycle profile of patented technologies.

The new data on the transfer of patents opens up new avenues of research. For example, now we are able to better analyze small small firms that specialize in innovations and the selling of those creations to larger firms. Plus we are now able to estimate the gains from trade in the market for patents (Serrano [46]) and to examine to what extent the move towards higher

[4] We define small innovators patents as those initially owned by corporations that were granted no more than 5 patents in a given year. Large innovators patents are those issued to corporations with more than 100 patents granted in a given year. Medium innovators patents make up the rest.

protection of intellectual property rights that occurred in the mid 1980s facilitated specialization and trade in patents. Heretofore, the new data will allow researchers to assess these questions in more detail than in previous studies.

In addition to the empirical literature on patents, our work also relates to the literature on markets for technology. To the best of our knowledge, Lamoreaux and Sokoloff [28][29] and this paper are the only ones that explore patent assignments to study markets for technology. They use a sample of sales of private inventors patents and provide a historical account of whether organized markets for technology existed in the late 19^{th} and early 20^{th} century. Our work complements previous research on strategic alliances and licensing. Theoretical work has analyzed the impact of licensing on the pattern of innovation, the gains from trade and the sale of ideas.[5] Empirical work has used data on strategic alliances and university technology transfer offices to examine the structure of licensing contracts, the emergence of specialized research organizations, the allocation of control rights, and technology transfer at universities.[6] To put this empirical work in contrast to ours, the main difference between the licensing and the transfer of patents is that while the former constitutes a permission of use or a promise by the licensor not to sue the licensee, the latter involves the transfer by a party of its right, title, and interest in a patent.[7]

This paper is organized as follows. Section 2 presents the model and describes some of its predictions. Section 3 explains the characteristics of the new data and section 4 documents the patterns. Section 5 concludes the paper. The reader who most interested in the patterns of transfer and renewal can skip sections 2 and 3 and go directly to 4. Finally, the appendix contains several tables.

2 A Model of patent transfers and renewals

It is useful to initially present an organizing framework for understanding some of the empirical regularities that we will develop later. This section presents a model detailing the transfer and renewal of patents. We will consider the problem faced by an agent who holds a patent and we will also make a number of predictions concerning both the probability of a patent being traded and its expiring.

[5] Gallini and Winter [16], Katz and Shapiro [27], Shepard [47], Anton and Yao [5] , Gans and Stern [13], etc.

[6] Some of the studies that have used data on strategic alliances and licensing data are Arora [6]; Lerner and Merges [32]; Anand and Khanna [3]; Arora, Fosfuri and Gambardella [7]; Gans, Hsu, and Stern [14], etc. Some studies that have used data on licensing by universities are Agrawal and Henderson [2], Sampat and Ziedonis [41], etc.

[7] Our paper also relates to the industrial organization literature on business transfers and exit, mergers, and reallocation (Dunne, Roberts, and Samuelson [12]; Pakes and Ericson [39]; Holmes and Schmitz [24]; Mitchell and Mulherin [34]; Andrade and Stafford [4]; Graff, Rausser and Small [17]; Maksimovic and Phillips [33]; Jovanovic and Rousseau [26].)

The problem for an agent is to decide whether to keep, sell, or let a patent expire. Pakes and Schankerman [37] and Schankerman and Pakes [42] examine the problem of a patent owner deciding in each period of whether or not to pay a renewal fee in a context with heterogeneity in the economic value of inventions. Building on their framework, we will consider that patents may be traded because some firms can generate higher revenue than others using a given patent, but transfering a patent and adopting the technology involves a fixed cost to be incurred by the buyer.[8]

The starting point of our theory is Pakes and Schankerman [37] and Schankerman and Pakes [42]. They examine the problem of a patent owner deciding in each time period whether or not to pay a renewal fee, and thereby extend the life of a patent, in a context with heterogeneity in the economic value of inventions. The contribution of our theory is to introduce the possibility that an alternative potential owners may have greater valuation for the patent than the current owner. But to transfer a patent to a new owner involves a resource cost, a cost of technology adoption, to be incurred by the buyer. In summary, whereas Pakes and Schankerman's framework has one margin, should the patent owner pay the fee for renewing the patent, our model has a second margin, should the cost of technology adoption be covered to reallocate the patent to an alternative owner.

Alternative owners could generate a greater patent value than a current one because of better production facilities, managerial skills, and complementary assets. To account for this possibility, we consider that the best potential buyer of a patent with current revenue x is characterized by an improvement factor $g^e \geq 0$ that generates revenue $y = g^e x$ and represents the arrival of opportunities for surplus-enhancing transfer via the sale of patents. We also assume that the sharing rule of the gains from trade is efficient and that the current owner obtains all the surplus. This seller-takes-all-of-the-surplus assumption will be useful for our analysis; however, allowing the buyer to capture some positive surplus as long as the sharing rule is efficient will not alter our qualitative results.

Let $V_a(x, g^e)$ be the expected discounted value of patent protection to the agent just prior to the a^{th} renewal of a patent with revenue x if kept by current owner, and with an improvement factor g^e when sold to the potential buyer. If the renewal fee is not paid, then the patent expires and $V_a(x, g^e) = 0$. If the renewal fee is paid, the owner earns the current revenue x and keeps the patent until the next renewal date. If the cost of technology adoption and the renewal fee are paid, then the buyer earns patent revenue y and obtains the ownership of the patent.

$$V_a(x, g^e) = \max\{0, V_a^K(x, g^e), V_a^S(x, g^e)\} \qquad a = 1, ..., L$$

[8] The model does not consider a number of important issues such as licensing, strategic considerations, asymmetry of information, the design and use of incentives in contracts of technology transfer, the demand for liquidity, etc.

Where L is the maximum legal length of patent protection, $V_a^K(x, g^e)$ and $V_a^S(x, g^e)$ are the values of keeping and selling the patent, respectively. The latter values are defined as the sum of the revenue of a patent of age a and the option value of the patent minus the renewal fee at age a, c_a:

$$
\begin{aligned}
V_a^K(x, g^e) &= x - c_a + \beta E_{g^e}[V_{a+1}(x', g^{e\prime}|x)] \\
V_a^S(x, g^e) &= y - c_a - \tau + \beta E_{g^e}[V_{a+1}(x', g^{e\prime}|y)]
\end{aligned}
$$

Where $\beta \in (0, 1)$ is the discount factor, τ is the cost of adopting a technology[9] and $E_{g^e}[.]$ is the expectation operator over the random variable g^e with cdf F_{g^e}. Finally, the initial patent revenue is distributed with cdf F_{x_1} and patent revenue depreciates deterministically between periods at a fixed rate $\delta \in (0, 1)$ as in Pakes and Schankerman. The deterministic rate implies that when the patent is kept, $x' = \delta x$, and when it is sold, $x' = \delta y$.

To illustrate the economic forces at play in the decision of a patent owner, consider a patent of age a with revenue x at the beginning of a period and with a potential buyer characterized by an improvement factor g^e. The patent will be sold when the improvement factor is large enough so that the fixed costs of adopting the technology can be amortized over time. If we look at an older patent with the same current revenue, it is less likely to be sold because when the patent horizon is shorter, a higher improvement factor is needed to amortize the costs of adoption. Furthermore, if we fix the age of the patent, we find that the higher the patent revenue x is, the lower the improvement factor needed to amortize the cost of adoption. A lower improvement factor is needed because the difference between the value of keeping and selling the patent, i.e., $V_a^S(x, g^e) - V_a^K(x, g^e)$, increases with x as does the difference between the revenue of the potential buyer and the current owner, $y - x$. These are the main trade offs in the decision problem of a patent owner.

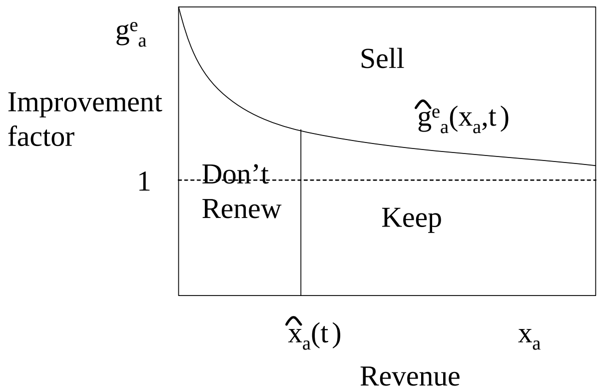
More formally, Serrano [46] shows that functions–$\widehat{g}_a^e(x, \tau)$ and $\widehat{x}_a(\tau)$–exist that divide the policy space into three areas (keep, sell or let the patent expire) as illustrated in Figure 1. The cutoff $\widehat{g}_a^e(x, \tau)$ is the improvement factor that makes a patent owner indifferent between selling or not selling a patent with revenue x and age a. The revenue $\widehat{x}_a(\tau)$ makes the owner indifferent between keeping the patent or letting it expire. An owner facing a potential buyer with an improvement factor above $\widehat{g}_a^e(x, \tau)$ will sell the patent. Moreover, as long as the improvement factor is lower than $\widehat{g}_a^e(x, \tau)$, patents with lower revenues than $\widehat{x}_a(\tau)$ will be allowed to expire and then ones with revenues higher than $\widehat{x}_a(\tau)$ will be renewed.

The model has two theoretical results, namely the selection and horizon effect, as well as a number of testable implications.[10] Serrano proves that for a fixed age, the function $\widehat{g}_a^e(x, \tau)$

[9] There is little evidence on estimates of costs of technology transfer. Ǎstebro [9] studies the adoption of both CAD and CNC technologies and finds that there are large fixed noncapital and capital costs of adoption.

[10] There are several key elements that allow Serrano to prove these results. One is that the cost of technology

Figure 1: The Policy Space



is decreasing with x, implying that the probability of a patent being traded is increasing with x. That is, the higher the revenue x is, the lower the improvement g^e needed for the owner of the patent to be indifferent between selling it or not. We call this the *selection effect* because traded patents–and especially those that have been recently traded–have, on average, a higher revenue prior to a potential trading date than the previously untraded ones. This selection effect will show why previously traded patents are more likely to be traded and less likely to be allowed to expire than the previously untraded ones as presented in Section 4. The second result illustrates that for a fixed patent revenue x, the function $\widehat{g}^e_a(x,\tau)$ is increasing with a, which implies that the probability of an active patent being traded decreases with age for a fixed revenue x. That is, as a patent with a fixed revenue x gets older, the owners must meet better potential buyers in order to be indifferent between selling the patent or not. We call this the *horizon effect* because a shorter horizon implies less time to amortize the cost of adopting a technology. The horizon effect will show why the probability of an active patent being traded decreases with age, with the exception of the renewal dates as presented in Section 4.

The fact that mandatory renewal fees in the U.S. patent system are not due annually creates some interesting testable implications. Our model predicts that two opposing forces determine the probability of a patent being traded the year immediately following its renewal date.[11] On the one hand, the probability of an active patent being traded may increase after a renewal date because the average revenue of the renewed patents is higher than the average revenue of

adoption is fixed and does not fully internalize how the difference between the value of selling or not selling a patent changes as the revenue and age of the patent varies, i.e., the cost of technology adoption is not proportional to the difference between the value of not selling and selling the patent (net of the cost). Another important element of the structure of the model is that the improvement factor g^e is independent of the age and revenue of the patent. This simplifies the process g^e and implies that the buyer's per period patent revenue depends on the revenue of the current owner. If the revenue of the potential buyer was independent of the revenue of the current owner, then neither the selection nor the horizon effect would generally hold.

[11] In the U.S. patent system, mandatory renewal patent fees are due at the end of the 4th, 8th and 12th year. If the fees are not paid, then the patent expires.

the existing patents immediately prior to the renewal date. Consequently, the sample selection generated by the renewal decision, and the result that patents with higher revenue are more likely to be traded (we will call this the renewal sample selection effect), implies a discrete jump in the probability that an active patent will be traded *immediately* following its renewal date.[12] On the other hand, this probability might decrease as the revenue of patents depreciate and their ages increase over the year immediately following their renewal dates. This is because when the revenue decreases with age, the selection effect implies that the probability of a patent being traded decreases; when a patent is older, the horizon effect implies that the probability of a patent being traded decreases as well. Therefore, we should observe a discrete jump in the empirical probability of an active patent being traded the year immediately following a renewal date only when the renewal sample selection is the dominant effect.

In short, we find a number of new implications. First, the selection effect implies that for fixed age a, the probability of an active patent being traded increases with its revenue. As a result, previously traded patents–and especially the recently traded–are more likely to be retraded and renewed than the previously untraded ones, and that the probability of an active patent being traded may increase immediately after a renewal date. Second, the horizon effect implies that for a fixed revenue x, the probability of an active patent being traded decreases with age, except in the year immediately after its renewal date when this probability may discretely increase.

Remark: This paper models the transfer of the ownership of patents but does not explicity consider the licensing of patents.[13] Because patent revenue can represent both the proceeds of adopting and using a technology, as well as the ones that the owner could additionally obtain by licensing the patent to others, the model can to some extent account for the licensing of patents. In this context, the improvement factor process illustrates the arrival of opportunities for surplus-enhancing via the sale of patents versus their licensing. One limitation of this explanation is that while in the current model[14] the opportunities for surplus-enhancing transfer via the sale of patents evolve stochastically, the implicit arrival of opportunities to license a patent does not because revenue is deterministic.[15] That is, when the revenue growth process is deterministic over time, we are explicity excluding the possibility that revenues could grow because of the arrival of licensing opportunities. Another limitation is that we assume that the

[12] This is because the distribution of per period revenue immediately after a renewal decision stochastically dominates the distribution of revenue prior to a renewal date.

[13] There is no systematic data on patent licensing revenue, but there is anecdotal evidence. IBM's licensing revenue was \$1.6 billion in the year 2000 (Berman[10] as reported in Merrill, Levin and Myers [48]). In 1996 U.S. corporations received \$66 billion in income from royalties of unaffiliated entities(Degnan[11]). Texas Instruments reported to have obtained \$1.6 billion in licensing royalties from 1996 to 2003(Grindley and Teece[19]).

[14] Serrano [46] considers a model where both the internal process of how revenues evolve as well as the arrival for surplus-enhancing transfer are stochastic. However, the internal process of growth of revenues is decreasing with the age of the patent.

[15] We thank a referee for pointing out this issue.

benefits of the sale versus the licensing of patents do not differ over the life cycle of patents. Furthermore, the economic process we have considered here assumes that buyers of patents are adopters and users of the acquired technology rather than firms specializing in managing patents. For instance, a firm could exclusively focus on managing a patent by licensing it to many others who can then adopt it[16], but firms exclusively managing patents are a rather new organizational form mainly associated with firms acquiring patents for prospective litigation purposes.

3 Measuring transfer of technology with the USPTO assignment data

There are several aspects of the assignment data that allow us to analyze in detail the transfer of technology. In contrast to strategic alliance and license transactions, the transfer of the ownership of patents is most often recorded because of the legal requirement that all assignments have to be filled with the USPTO in order to be legally binding.[17] In addition, technology transfer agreements in the form of assignments contain patent numbers, which allow us to link these transfers to technology fields, patentees and patent characteristics.[18] Therefore, we can analyze aspects of the dynamics of the transfer of technology in more detail than previous studies have done.

The rest of this section is divided into three parts. First, we present the contents of the assignment data. Second, we discuss the general principles that led to the decisions made in the construction of the new data set. Third, we describe the contents of the new data set.

Original assignment data The main source of our data is the USPTO Patent Assignment Database . Patent assignments acknowledge the transfer by a party of the rights, title and interest in a patent or bundle of patents. A typical assignment is characterized by a unique identifier (i.e., reel frame), the name of the buyer (i.e., assignee) and the seller (i.e., assignor),[19] the date that the assignment was recorded at the patent office (i.e., recorded date), the date the private agreement between the parties was signed (i.e., execute or signed date), the number of patents or patent applications included in the assignments, and the type of the assignment,

[16] We thank a referee for pointing out this issue.

[17] The recordation of the transfer of patents as well as many other transactions of assets like houses is not mandatory, but only recorded transfers of patents at the USPTO act as evidence of a bona fide purchase in courts. Furthermore, anecdotal evidence from interviews with patent lawyers strongly supports the effective recordation of transfer of patents.

[18] One notable exception where a sample of strategic alliances is linked to patent numbers is the work of Gans, Hsu, and Stern [14]. They focused on a small sample of licensing agreements of biotechnology companies.

[19] The names of the buyer and seller in the Patent Assignment Data Base were never standarized by the USPTO.

which acknowledges the rational of the transfer (i.e., brief).[20] We obtained records of the daily trades that occurred between August 1, 1980 to December 31, 2001.

Data construction Here we will describe the three main principles that led to the decisions made in the construction of the data set. The details of the procedures we use to deal with the assignment data are explained in the on-line appendix of this paper. First, since our main interest in the new data ultimately lies in the reallocation of the ownership of patents for technological purposes, we separate assignments recorded as administrative events, such as a name change, a security interest, a correction, etc. Second, we focus on the transaction of patents across firm boundaries. Since many recorded assignments represent transactions between inventors-employers and their employees-assignees as of the grant date of the patent, we identify their names and exclude these assignments (i.e., first assignments). Subsequent assignments (i.e., reassignments) of these patents are included in our data. For future reference, we define “trades”, “transfers” and "reassignments" as reallocations of patents across firm boundaries. Finally, we link the assignment records at the patent level to existing patent data on patent renewals, citations, generality, technology field, the name of the assignee as of the grant date of the patent, and other patent characteristics.

Contents of the transfer data. The new data set is a panel of U.S. utility[21] patents granted since January 1, 1983 and subject to renewal fees[22] whose history of trades and renewal decisions took place up to the end of the year 2001. We identified six types of patentees according to the grant dates of their patents (individual private inventor patents; unassigned patents as of the grant date owned by the inventors; small, medium and large innovators; and government agencies).[23] Similarly, we divided patents into six technology fields (chemical, computer and communications, drugs and medical, electrical and electronics, mechanical and other). In addition, we categorized patents by their importance and scope, as measured by the

[20]Patent transactions can be recorded for several reason. To acknowledge the outright sale of patents (i.e., assignment of assignors), the union of two or more commercial interests (i.e., mergers), the securitization of a patent as a collateral (i.e., security interest), the change of name of its current owner (i.e., change of name) and the correction of a previous record (i.e., pro nunc tunc), etc.

[21]Utility patents represent the most common type of patent.

[22]In the U.S. patent system, patents applied for after December 12, 1980 are subject to renewal fees at the end of years 4, 8 and 12 since its grant date. If renewal fees are not paid, then the patents expire. In the U.S. system, the maximum possible term of an issued patent (assuming that any required renewal fees are paid) was 17 years until June 8, 1995. We use patents granted since January 1, 1983 because on average the application period of a granted patent is 2.5 years. We excluded patent applications that were never granted because the USPTO does not make this data available for patents applied for before 2001.

[23]When a patentee is a corporation, we can add a measure of the size of the firm as of the grant date of the patent. While we would like to use standard measures of firm size like employees or assets, it is difficult to find such measures for all the patentees. Small innovators patents are defined as those owned by corporations that were granted no more than 5 patents in a given year. Large innovators patents are those issued to corporations with more than 100 patents granted in a given year. Medium innovators patents make up the rest.

number of patent citations received and their respective generality (patent citations received and generality are defined as in Hall, Jaffe and Tratjenberg [22]). Table A-1 in the appendix provides summary statistics about granted and traded patents by type of patentee.[24]

The new data is not without drawbacks. First, after a patent has been granted, the name of the first buyer, and all its subsequent sellers and buyers, are not standardized by the USPTO. Second, we cannot distinguish the acquisition of a firm from the acquisition of a bundle of patents.[25] Third, we do not have information on the price paid for the patents transferred. Fourth, one must recognize that patents which are traded in large blocks might not represent technology transfers. As a result, the economic forces that we highlight in our model will be more salient for small innovators and individually owned patents.[26] Fifth, the data does not allow us to distinguish between patents being acquired by firms who adopt the technology and firms who might specialize in managing patents by licensing them to many others who can then adopt them. Firms exclusively managing patents, however, are a rather new organizational form mainly associated with firms acquiring patents for prospective litigation purposes. For this reason, we expect that the majority of the transfers in our data set represent the adoption of a technology. Finally, since we have no systematic data on licensing transactions at the patent level, we cannot assure whether our empirical findings also apply to alternative methods of technology transfer like the licensing of patents.

4 Patterns of the transfer and renewal of patents

Our empirical analysis focuses on three aspects. First, we examine the rates of transfer and renewal for several types of patentees. Second, we study the rates of transfer and renewal across technology fields as well as the differences in the importance of small type of patentees versus their larger counterparts in the rates of transfer. Third, we look at the impact of patent characteristics such as age, patent citations received, and generality in the dynamics of the transfer and renewal of patents. The robustness of the patterns is analyzed using a logit model.[27]

[24] We thank a referee for suggesting we consider the variable generality.

[25] In the hypothetical case that a small innovator was acquired rather than a bundle of its patents, we consider that it might be acquired mainly because of the value of its technological assets. In this scenario, the transfer will likely involve a cost of adopting and, especially setting up the technology in the new firm. Thus, to some extent, the acquisition of an innovative firm would not necessarily be different than the transfer of its patents.

[26] Studying both small innovators and individually-owned patents is interesting in their own right, given the importance they play in the innovation process (Acs and Audretsch [1]; Arrow [8]).

[27] The parametric analysis is useful because facilitates to test the robustness of our findings. Similar results should be obtained analyzing the data using alternative parametric models.

Table 1: Proportion of Patents Traded and Expired by Type of Patentees

	Individual owners			Corporations (Innovators)				Govt. Agenc.
	All	Unassigned	Priv. Inventors	All	Small	Medium	Large	
A. Proportion of patents traded over their life cycle by type of patentees								
Unweighed	12.4	12.2	16.2	14.0	17.5	14.6	10.5	4.1
Weighed by citations	19.0	18.7	24.1	17.2	24.0	17.4	11.4	6.0
B. Proportion of patents expired up to the last renewal fee by type of patentees								
Unweighed	77.5	77.7	73.1	55.1	60.3	55.5	50.0	83.5
Weighed by citations	68.4	68.9	62.0	43.2	48.8	42.8	39.1	74.4

Note: the proportions of this table are created using a pooling of all U.S. patents granted from 1983 to 2001.

Table 2: Proportion of Patents Traded and Expired by Technology Field and Type of Patentee

	Chemical	Computer & Comm	Drugs & Medical	Elec. & Electro.	Mechanical	Other	All
A. Proportion of patents traded over their life cycle by patent categories							
Individual owned patents	16.1	15.8	17.0	14.7	11.6	10.1	12.4
Unassigned	16.1	15.6	16.8	14.4	11.3	9.9	12.2
Priv. Inventor	15.7	19.1	20.1	19.5	16.1	13.7	16.2
Corporations (Innovators)	15.0	13.0	16.0	14.0	12.3	14.9	14.0
Small	17.2	23.9	20.1	18.2	15.7	16.2	17.5
Medium	15.8	16.9	14.2	15.4	12.0	14.1	14.6
Large	12.5	7.9	13.3	11.2	8.5	12.3	10.5
Govt. Agencies	4.0	2.6	4.4	4.6	4.7	3.2	4.1
All	14.9	12.9	16.0	13.8	12.0	13.1	13.55
B. Proportion of patents expired up to the last renewal fee by patent categories							
Individual owned patents	77.5	73.0	69.3	68.4	74.1	81.1	77.5
Unassigned	72.8	69.8	69.0	74.6	79.3	81.3	77.7
Priv. Inventor	75.6	62.3	60.1	66.3	77.0	77.1	73.1
Corporations (Innovators)	58.3	44.6	54.5	51.9	56.7	60.1	55.1
Small	59.0	54.2	53.2	58.7	62.4	63.9	60.3
Medium	58.5	46.6	54.1	52.5	57.2	57.3	55.5
Large	57.6	40.6	59.1	48.1	49.0	53.6	50.0
Govt. Agencies	80.7	91.6	65.1	84.3	86.5	86.8	83.5
All	60.0	47.3	57.4	55.1	61.7	67.9	59.55

Note: the proportions of this table are created using a pooling of all U.S. patents granted from 1983 to 2001 and their trading and renewal decisions.

4.1 The transfer and renewal of patents across type of patentees

Our analysis of the transfer and renewal data begins by describing the rates of transfer across type of patentees. Table 1A reports both the values of the probability of a patent being traded over its life cycle and the same probability weighted by the total number of patent citations received.[28] There are two elements from this table that we would like to highlight. First, there is a substantial difference in the rates of transfer across type of patentees, with individual private inventor and small innovators selling respectively 16.2% and 17.5% of their patents. Meanwhile, large innovators and government agencies have the lowest rates of transfer with 10.5% and 4.1% of their respective patents. Second, when we weight the rates of transfer by the importance of the patent, as measured by patent citations received, the rates increase substantially, especially for small innovators and individual owners (unassigned patents and private inventors). As a result, the differences in the rates of transfer between type of patentees, now measured in "importance", are much larger than in absolute rates. For instance, while small innovators transfer 17.5% of patents and their larger counterparts transfer 10.5%, the same rates weighted by patent citations received are 24% and 11.4%.[29]

The expiration rates of patents by the last renewal fee at age 13 also vary substantially across type of patentees. Table 1B presents these rates. The evidence reveals that larger assignees are more likely to renew their patents than both their smaller counterparts and invidual inventors. For instance, the cummulative expiration rates of small innovators and individual owners are respectively 77.5% and 60.3%, while just 50% of large innovators patents are let to expire.

The comparison of the transfer and renewal rates reveals substantial differences across type of patentees, with small innovators and individual owner patents more likely to be traded and to expire than those held by larger patentees. This evidence is consistent with a process of arrival of substantial opportunities for surplus-enhancing transfer via the sale of patents from small to large patentees.

4.2 The transfer and renewal of patents across technology fields

The next aspect we focus on is the transfer and renewal of patents across technology fields. We have divided technology fields into six groups (chemical, computer and communication, drugs and medical, electricity and electronics, mechanical and other). Table 2A presents the cross-

[28] Here, total patent citations are the total number of citations received by the maximum legal length of patent protection. This is the sum of citations received from the patent's grant date up until the maximum legal length of patent protection. Similar results are obtained when the weighs are based on the total citations received by a given year, i.e., that is the sum of patent citations received from the patent's grant year until the year the patent is up for trade or renewal.

[29] I will be omitting the standard errors of the proportions. They are small because the number of observations is large. They range from 3.6 times smaller than the point estimates for computer and communication patents held by government agencies to 155 times smaller than the estimates for patents held by corporations.

tabulations of the cummulative transfer rates across technology fields and type of patentees. The bottom of the table presents the aggregate rates of transfer by technology field. The column at the far right shows the aggregate rates of transfer by type of patentee.

There are three aspects in this table that are noteworthy. First, there is some variation in the aggregate rates of transfer across technology fields. For instance, the lowest rate of transfer is 12% in the mechanical field while the highest rate is 16% in drugs and medical. Second, and perhaps more interesting, is that there are large differences across technology fields between the rates of transfer of small patentees and their larger counterparts. For instance, small and large innovators in the computer and communications technology field transfer respectively 23.9% and 7.9% of their patents; meanwhile, their rates of transfer in the chemical field are 17.25 and 12.5% respectively. Third, these differences in the relative importance of the rates of transfer of type of patentees are not necessarily larger in the technology fields with the highest rates of transfer. In particular, while 14.9% of chemical patents are traded, the rate of transfer is just 12.9% in the computer and communications technology field.

Table 2B reports the rates of expiration across technology fields by the last renewal date at age 13. We also find substantial differences in the proportion of patents allowed to expire across technology fields, ranging from a low of 47.3% in the computer and communication field to a high of 67.9% in the miscellaneous (i.e., other) field.[30] Another noteworthy finding expressed in this table is that while the differences in cummulative expiration rates of small versus large innovators are of the order of 10 to 20 percentage points in the computer and communication, electric and electronics, mechanical and other fields, the difference vanishes in the chemical field and even reverses in the drugs and medical field where large innovator patents are more likely to expire than those held by smaller innovators.

In short, the results reveal that the rates of transfer, and especially the expiration rates, vary across technology fields and that there are substantial differences in the rates of transfer of smaller versus larger type of patentees across technology fields. We think the findings on the transfer of patents suggest that the determinants of specialization in research may not necessarily be the same ones that determine the aggregate levels of transfer of patents across technology fields.

4.3 Patent characteristics and the transfer and renewal of patents

In this section we move on to examine the impact of a number of factors in the probability of a patent being traded and allowed to expire, as well as the life cycle properties of the transfer

[30] While the differences in the rate of transfer and expiration across technology fields and patentees are significant, they could also depend on the patterns of patenting by patentees and the characteristics of their patents. To account for this possibility, we run logit models for both the trading and the expiring decision regressed on a number patent characteristics as controls. The differences were somewhat smaller, but the rates were similar.

and renewal of patents.[31]

We begin by examining the impact of the total number of patent citations received by a given age on the decision to transfer a patent.[32] To address this issue, we regress the decision to trade an active patent on the total number of patent citations received by a given age and technology field dummies.[33] The positive coefficient of the total number of patent citations received indicates that patents with a higher number of total patent citations received by a given age are more likely to be traded (see Table A-2A in the appendix). For instance, we find that an extra citation increases the predicted probability of a small innovator patent being traded at age 7 by about 0.02 percentage points as compared to the mean of the sample, i.e., increasing the rate from 1.92% to 1.94%. Moreover, this predicted probability increases to 2.13% when it is evaluated at the 95 percentile of total citations. The estimates we find are significant at standard levels, they are robust to a number of specifications, and the dummy variables are jointly significant.[34] To the extent that patent citations by a given age are positively correlated with revenue to patent protection, this pattern is consistent with the result that, for a fixed age, patents with higher revenues are more likely to be traded, i.e., the selection effect.

In addition, to address whether more frequently cited patents are more likely to be renewed, we regress the decision to let an active patent expire on the total number of patent citations received by a given age and technology field dummies. The negative coefficient of the patent citations received illustrates that frequently cited patents are more likely to be renewed (see Table A-2B in the appendix). We find that an extra citation decreases the predicted probability of a small innovator patent being allowed to expire at age 13 by about 1 percentage point as compared to the mean of the sample, i.e., decresing from 36.9% to 35.9%. Furthermore, this predicted probability decreases to 27.1% when evaluated at the 95 percentile of total citations. The estimates we find are significant at standard levels, they are robust to technology field and type of patentee dummies, and the dummy variables are jointly significant.

[31] I will be generally omitting the standard errors of the proportions in the Tables below. Standard errors are generally small because the number of observations is large. We have calculated upper bounds of the standard errors based on the number of observations of patents granted from 1983 to 1985. They range from 2 times smaller than the point estimates of patents traded at age 17 that were previously traded one year ago, to 32 times smaller than the point estimates of patents traded at age 2 that were not previously traded. The reader can find the upper bounds of the standard errors in the on-line appendix.

[32] Since there is no systematic data on licensing, we are consequently neglecting the possibility that some patents that are not sold may be licensed. To the extent that licensed patents were more likely to receive patent citations than patents neither transferred nor licensed, the effect of patent citations received as a determinant to the decision to sell versus neither selling nor licensing a patent could be under estimated.

[33] Here, total number of patent citations received by a given age is the sum of citations received from the grant year of the patent to the year it is up for trade or renewal. Similar results are obtained when using the total number of citations received by the maximum legal length of patent protection.

[34] There is one exception: the regression for the sample of patents of large innovators. The negative coefficient of patent citations is based on patents that belong to electrical and electronics. In the rest of the technology fields, the coefficient is positive and significant or not statistically significant. Moreover, when we estimate the probability of a *granted* patent being traded using the same explanatory variables, the effect of citations is significant across type of patentees and robust to technology fields.

The next issue we address is the impact of patent generality on both the transfer of patents and renewal. First, we look at the transfer decision. To do this, we run a regression of the decision to trade a patent on patent generality and technology field dummies. The positive coefficient of generality indicates that patents with higher generality are more likely to be traded (see Table A-3A in the appendix). For instance, we find that the predicted probability of a small innovator patent being traded at age 9 when evaluated at the sample mean is 2.00%; and it increases to 2.17% at the 95 percentile of generality. These estimates are significant at standard levels, they are robust to technology field and type of patentee dummies, and the dummy variables are jointly significant.[35]

The second aspect of generality we look at is its relationship with the renewal of patents. The results of regressing the decision to let a patent expire on patent generality and technology field dummies reveal that patents with higher generality are more likely to renewed (see Table A-3B in the appendix). In particular, we find that the predicted probability of a small innovator patent expiring at age 9 when evaluated at the sample mean of generality is 27.8%,decreasing to 26.0% when evaluated at the 95 percentile of generality. The estimates we find are statistically significant at standard levels and they are robust to technology field and type of patentee dummies. In addition, when we add the variable total number of patent citations received to the generality regressions, we find that the coefficient of patent generality maintains a substantial explanatory power in the trading decision but its importance is largely reduced in the regression of the expiring decision. That is, the generality strongly affect the trade of patents and mildly affect the renewal decision. This result confirms that patent generality captures well the arrival of opportunities for surplus-enhancing transfer as interpreted by the improvement factor process of the model of patent transfers.

We now turn our attention to the longitudinal aspects of the data. We first compare the rates of trading and renewal of previously traded and untraded patents. In assessing the process of technology transfer, one must understand whether the fundamental aspect of technology transfer is dominated by a substantial arrival of opportunities for surplus-enhancing transfer or by finding a good match between a technology and a firm. The first process may involve subsequent transfers of a patent as newer opportunities for surplus-enhancing transfer appear overtime. The second process may be characterized by previously traded patents displaying lower rates of transfer than the untraded ones, as trades are supposed to enhance the match between firms and patents. Table 3 presents the proportion of active patents traded and left to expire as a function of whether or not the patents were previously traded and the number of years since their last trade. The figures in the table are the pooled proportion of small innovators patents granted from 1983 to 2001. There are two results we want to highlight. First, the probability of an active patent being traded for a previously traded patent is higher

[35] Government agency patents are an exception to this result.

Table 3: Patents Traded and Expired for Small Innovators

A. Patents Traded as a Percentage of All Active Patents

			Previously Traded (Years since last trade)				
Age of Patent (Years)	All	Not Previously Traded	Any Year	1	2	3	4
1	2.505	-	-	-	-	-	-
2	2.335	2.225	5.287	5.287	-	-	-
3	2.201	2.068	4.753	5.265	4.244	-	-
4	2.179	2.007	4.453	5.043	4.291	4.025	-
5	2.220	1.989	4.407	5.324	4.527	3.840	3.769
6	2.017	1.753	4.068	4.935	4.127	3.765	4.103
7	1.902	1.621	3.805	4.963	3.750	3.796	3.567
8	1.885	1.565	3.801	4.962	3.860	4.075	3.595
9	1.937	1.566	3.789	4.825	3.162	3.915	3.878
10	1.779	1.404	3.494	3.839	3.369	4.825	3.221
11	1.676	1.354	3.042	3.937	3.618	3.671	2.836
12	1.540	1.264	2.626	3.276	3.851	2.537	2.411
13	1.675	1.331	2.868	2.001	2.273	4.721	3.280
14	1.680	1.330	2.847	3.234	2.774	4.513	4.070
15	1.362	1.008	2.497	2.802	2.189	2.698	3.0
16	1.157	0.861	2.075	2.229	1.559	3.817	1.439
17	0.841	0.608	1.539	1.818	1.181	2.821	1.976

B. Patents Expired as a Percentage of All Active Patents

			Previously Traded (Years since last trade)				
Age of Patent (Years)	All	Not Previously Traded	Any Year	1	2	3	4
5	18.399	18.958	12.707	6.696	12.148	14.456	16.08
9	29.143	30.077	24.087	11.253	18.650	22.070	23.407
13	33.014	34.131	28.830	15.515	22.663	24.280	29.614

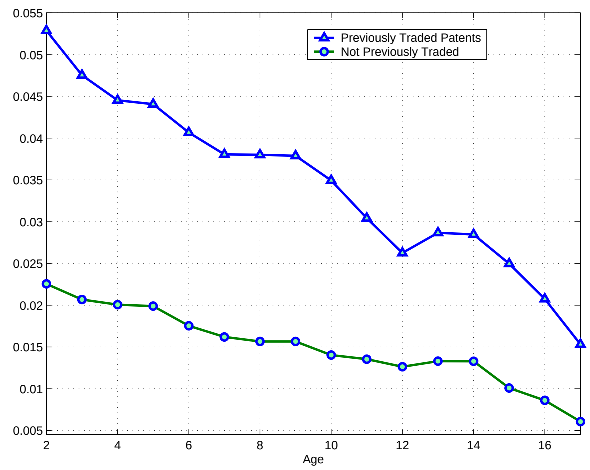
Note: the proportion of this table are created using a pooling of all U.S. patents granted from 1983 to 2001 and their trading and renewal decisions.

at any patent age than the one of an untraded one. As a matter of fact, the probability of a small innovator patent being traded early in its life cycle, conditional on having being previously traded, is about twice as large as the probability of it being traded for an untraded patent. This difference remarkably shrinks over the life cycle of patents (as showed in Figure 2). The second result we want to highlight is that the probability of a previously traded patent expiring at any renewal date is lower than that of an untraded patent. To assess the robustnes of these results, we separately regress the decision to trade a patent and the one to let it expire on whether a patent has been previously traded with a number of controls. The estimated coefficient of the variable previously traded is positive for the trading decision and negative for the expiring one. Both estimates are statistically significant in a number of specifications and the dummy variables are jointly significant, which confirm our findings (see Table A-4 in the appendix for more details). These findings are consistent with a theory of technology transfer where the arrival of opportunities for surplus-enhancing transfer is a significant element.

The second aspect of the longitudinal data we explore is the extent to which recently traded patents are more likely to be traded and renewed than the rest of those previously traded. The figures presented in the last four columns of Table 3 show that recently traded patents are indeed more likely to be traded and renewed than other previously traded patents.[36] To address

[36] In this case the standard errors of the proportions of older patents being traded are somewhat higher than

Figure 2: The Number of Patents Traded as a Proportion of Active Patents Conditional on Having Been Previously Traded or Not (Small Innovators)



the robustness of this pattern, we separately regress both the decision to traded a patent and the decision to allow a patent to expire on the numbers of years since its last trade, the numbers of years since its last trade squared, and technology field dummies. The estimates confirm that our results are significant at standard levels, that they are robust to technology field and type of patentee dummies, and also that the dummy variables are jointly significant. Furthermore, when we run separate regressions for each patentee, the results are similar (with.few exceptions like patents of government agencies).

The third aspect we examine is the transfer and renewal decision over the life cycle of patents. The first column of Table 3 presents patents traded and patents expired as a percentage of all active small innovator patents. There are three elements of this table concerning the life cycle profile of patents that are noteworthy. First, the figures representing the probability of an active patent being traded reveal that this probability decreases with age, except in the year immediately after a renewal date. This fact is consistent with the result that we previuosly presented for which, for a fixed revenue, the probability of a patent being traded decreases with age because a shorter horizon implies less time to amortize costs of technology adoption.model's horizon effect, i.e., horizon effect. Second, the probability of an active patent being traded increases the year immediately after a renewal date. To assess whether these jumps are statistically significant as well as robust across technology fields and type of patentees, we regress the decision to trade a patent on age, technology field dummies and type of patentees. We find that the estimates are indeed significant, robust to a number of specifications and the dummy variables are jointly significant. Using these estimates, which are reported in Table A-6,

in other proportions previously presented because the number of observations decreases when we condition on the number of years since the last trade and especially for older cohorts of granted patents.

we find that the jumps are significant at standard levels for the sample of all patents and for individually owned patents (private inventors and unassigned patents). For small innovators, the jumps are also significant but at somewhat higher levels.[37][38] According to predictions of the model of patent transfers, the fact that the jumps exist imply that the renewal sample selection effect dominates the horizon effect. Finally, the third noteworthy element is the rate at which active patents are allowed to expire over their life cycle. The figures at the bottom of the first column of Table 3 reveal that this rate increases with patent age, which is consistent with values to patent protection substantially decreasing over the life cycle of patents.

Remark: It is not easy to find metrics to assess how economically and quantitatively important the jumps of the probability of a patent being traded immediately after a renewal date may be. One way is to test whether the jumps are robust across technology fields and type of patentees, as well as statistically significant, as we have already discussed. Another way to assess the importance of these jumps may be to compare their levels in the years immediately after renewal dates with those of previous years. Using this metric, we find that the jumps increase the probability of a patent being traded up to the levels attained two, three or even four years prior to the year immediately after a renewal date. Therefore, we conclude that these jumps seem to be both economically and quantitatively important, especially for individual inventors and the smaller assignees.[39]

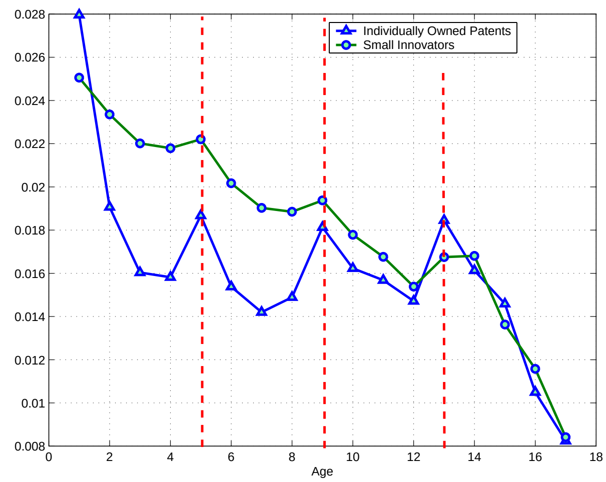
In summary, we find that active patents with a higher number of patent citations received and generality, as well as previously traded patents (especially the recently traded) are more likely to be traded and renewed. The data also reveals that the probability that an active patent

[37] We test the following three null hypothesis for all the samples: *i*) age_year4≥age_year5; *ii*) age_year8≥age_year9; and *iii*) age_year12≥age_year13. If the p values are sufficiently low, then we can reject the hypothesis and conclude that the jumps are significant at a certain statistical significance level. We obtain the following p values. The first to last number in the parenthesis represent null hypothesis i to iii. All innovators (0.2819; 0.00; 0.00); individually owned patents (0.00; 0.00; 0.00), unassigned (0.00; 0.00; 0.00), private inventors (0.0529; 0.0755; 0.03776), small innovators (0.140; 0.1468; 0.0308); medium innovators (0.9697; 0.0125; 0.00); large innovators (0.00; 0.00; 0.6461) and government agencies (0.777; 0.00; 0.4490). Similar results are obtained when the sample proportions are used instead of the age dummies as well as when technology field controls are added.

[38] When we estimate the probability of a patent being traded on age dummies and total citations received by a given age, the jumps of the age dummies after a renewal date are smaller than when the variable total citations received by a given age is not included. To the extent that the number of total citations received by a given year is positively correlated with the revenue to patent protection of a patented innovation, the result is consistent with the implications of the theoretical model considered in the paper. The fact that these jumps do not dissapear may be because total citations received might not a perfect measure of the value to patent protection. Patent citations received are not necessarily a perfect measure of value to patent protection because they are not received contemporaneously with patent protection, they may represent spillovers and can be made as a reference to prior art.

[39] To investigate further the issue of the jumps in the probabilty of a patent being traded immediately after a renewal date, we examine the effects of focusing on a sample of only patents that are not let to expire. In this context we find that there are no jumps in the rate of transfer immediately after a renewal date. This suggests that the mechanism that our model highlights works, i.e., it is necessary that the relative proportion of high value patents increases after their lower value counterparts are left to expire on a renewal date.

Figure 3: The Number of Patents Traded as a Proportion of Active Patents (Small Innovators and Individual Owned Patents)



willl be traded decreases with age, with one exception, which is the year immediately after a renewal date. Finally, we also show that the probability of an active patent being allowed to expire increases with age.

5 Conclusion

This paper has provided a summary of the patterns revealed by a new data set on the transfer and renewal of patents. This empirical work has focused on three aspects of the data. The first aspect we looked at was whether the rates of transfer and renewal differed by the type of patentees. The evidenced revealed that small innovators and private inventors are the most active sellers of patents while government agencies and large innovators are the least. Secondly, we studied the variation of the rates of transfer and renewal across technology fields and examined the relative importance of the smaller type of patentees versus their larger counterparts for each technology field. We found some differences in the aggregate rates of transfer and renewal across technology fields. However, the differences were much larger when we looked at the relative importance of the smaller type of patentees versus the larger ones. For instance, in the computer and communications field, small innovators transfer 23.9% of their patents while large innovators only sell 7.9%; however, in the chemical field, the sales rates are 17.2% and 12.5% for small and large innovators respectively. We think this fact can help us learn something about where the benefits of specialization may be more important. Third, we analyzed the impact of patent characteristics on the rates of transfer and renewal. We showed that the probability of a patent being traded and the probability of a patent being allowed to expire depended on a number of factors–the age of the patent, the number of citations received by a given age, the patent generality, and whether the patent had been previously traded or not. We found that younger, frequently cited, more original, and recently traded patents were more likely to be traded and renewed. Finally, we interpreted this evidence using a model of patent transfers and renewal in a context with the arrival of opportunities for surplus-enhancing transfer (i.e., gains from trade) and costs of technology adoption.

The new data can also open new avenues for research. One example would be to estimate the gains from trade in the market for patents and quantify the costs of technology adoption (Serrano [46]). Another example could be to analyze to what extent the move towards higher protection of intellectual property rights, which occurred in the mid 1980s, facilitated trade in patents. An interesting extension to our data work would be to standarize the names of buyers and seller of patents and link them to the characteristics of their firms. This extension would permit us to study whether patent property rights tend to be transferred at the local level (like spillovers do), to explore whether patents are acquired by firms with complementary innovations, and to examine whether small firms specialize in the creation of knowledge and then sell their patents to their larger counterparts. We leave these topics for future research.

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Table A-1: Summary Statistics of the Number of Patents Traded and Untraded over their Life Cycle

	Individually Owned		Corporations			Govt. Agen.
	Unassigned	Priv. Inventors	Small	Medium	Large	
Total	304,087	17,654	453,683	567,081	565,582	25,383
Traded	28,044	2,185	54,533	53,359	31,540	809
Not traded	276,043	15,469	399,150	513,722	534,042	24,574

Table A-2: Estimates of the Logit Regressions of the Decision to Trade or Allow a Patent to Expire Conditional on the Number of Patent Citations Received

	Individually Owned			Corporations (Innovators)				Govt. agen.	All	All#
	All	Unassigned	Priv. inv.	All	Small	Medium	Large			
A. Trading Decision										
total_citations	0.0163	0.0162	0.0174	0.00537	0.0109	0.00491	-0.00250	0.00432	0.00703	0.00744
	(0.0007)	(0.0007)	(0.0025)	(0.0003)	(0.0005)	(0.0005)	(0.0009)	(0.0060)	(0.0003)	(0.0003)
Obs	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070	12876456	12876456
B. Expiration Decision										
total_citations	-0.0406	-0.0406	-0.0394	-0.0522	-0.0834	-0.0572	-0.0480	-0.0529	-0.0532	-0.0499
	(0.0008)	(0.0009)	(0.0032)	(0.0004)	(0.0087)	(0.0007)	(0.0006)	(0.0027)	(0.0003)	(0.0003)
Obs	373918	352559	21359	1911564	559918	712799	638847	35882	2321364	2321364

Note: all regressions include age and technology field dummies. # The estimates of last column also include type of patentee dummies.
*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level.

Table A-3: Estimates of the Logit Regressions of the Decision to Allow a Patent to Expire or Being Traded Conditional on Patent Generality

	Individually owned			Corporations (Innovators)				Govt. agen.	All	All#
	All	Unassigned	Priv. inv.	All	Small	Medium	Large			
A. Trading Decision										
generality	0.2109	0.2092	0.2051	0.2146	0.1975	0.1749	0.2125	-0.0928***	0.2119	0.2028
	(0.0162)	(0.0168)	(0.0602)	(0.00779)	(0.0122)	(0.0127)	(0.0169)	(0.1020)	(0.0070)	(0.0070)
Obs	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070	12876456	12876456
Used	1717383	1617743	99640	9527208	2707508	3485280	3334430	150170	11395526	11395526
B. Expiration Decision										
generality	-0.0958	-0.0940	-0.1110	-0.1666	-0.1407	-0.2012	-0.1670	-0.1224	-0.1681	-0.1560
	(0.0108)	(0.0111)	(0.0465)	(0.00597)	(0.0101)	(0.00980)	(0.0114)	(0.0352)	(0.0051)	(0.0052)
Obs	373918	352559	21359	1911564	559918	712799	638847	35882	2321364	2321364
Used	331408	312327	19081	1721853	501791	637128	582934	31232	2084493	2084493

Note: all regressions include age and technology field dummies. # The estimates of last column also include type of patentee dummies.
*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level.

Table A-4: Estimates of the Logit Regressions of the Decision to Trade and Expire a Patent for Previously Traded Patents

	Individual Owners			Corporations (Innovators)				Govt. agen.	All	All#
	All	Unassigned	Priv. inv.	All	Small	Medium	Large			
A. Trading Decision										
Previouslytraded	1.0926	1.1052	0.8894	0.9976	0.8425	0.8793	1.1451	0.8631	1.0317	0.9428
	(0.0156)	(0.0163)	(0.0570)	(0.00775)	(0.0116)	(0.0130)	(0.0178)	(0.1533)	(0.00692)	(0.00697)
Obs	1647334	1551961	95373	9145965	2610335	3381661	3153969	149687	10942986	10942986
B. Expiration Decision										
Previouslytraded	-0.8723	-0.8730	-0.8355	-0.1663	-0.3341	-0.1060	-0.1762	-1.0472	-0.3155	-0.3554
	(0.0128)	(0.0133)	(0.0492)	(0.00649)	(0.0102)	(0.0104)	(0.0148)	(0.0751)	(0.00576)	(0.00589)
Obs	373918	352559	21359	1911564	559918	712799	638847	35882	2321364	2321364

Note: all regressions include age and technology field dummies. # The estimates of last column also include type of patentee dummies.
*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level.

Table A-5: Estimates of the Logit Regressions of the Decision to Trade and let a Patent Expire Conditioning on the Number of Years Since the Last Transfer

	Individual Owners			Corporations (Innovators)				Govt. agen.	All	All#
	All	Unassigned	Priv. inv.	All	Small	Medium	Large			
A. Trading decision										
tradedyearsago1	-0.1929	-0.2014	0.0788***	-0.1091	-0.0964	-0.1639	-0.028***	0.5869*	-0.1235	-0.1293
	(0.0177)	(0.0183)	(0.0715)	(0.0092)	(0.0136)	(0.0150)	(0.0232)	(0.2830)	(0.0081)	(0.0081)
tradedyearsago^2	0.00939	0.0100	0.0004***	0.0046	0.0046	0.0101	-0.0079	-0.0728*	0.0055	0.0058
	(0.0016)	(0.0016)	(0.0068)	(0.0008)	(0.0012)	(0.0013)	(0.0023)	(0.0293)	(0.0007)	(0.0007)
Obs	1647334	1551961	95373	9145965	2610335	3381661	3153969	149687	10942986	10942986
Used	156274	144592	11682	672783	271308	260889	140586	4213	833270	833270
B. Expiration decision										
tradedyearsago	0.4047	0.4141	0.2999	0.3594	0.3192	0.3565	0.4298	0.4984	0.370	0.3656
	(0.0189)	(0.0196)	(0.0694)	(0.0089)	(0.0139)	(0.0143)	(0.0202)	(0.1130)	(0.0080)	(0.0080)
tradedyearsago^2	-0.0231	-0.0237	-0.0151	-0.0223	-0.0204	-0.0210	-0.0279	-0.0374*	-0.0226	-0.0225
	(0.0015)	(0.0015)	(0.0053)	(0.0007)	(0.0011)	(0.0011)	(0.0016)	(0.0094)	(0.0006)	(0.0006)
Obs	373918	352559	21359	1911564	559918	712799	638847	35882	2321364	2321364
Used	39844	36906	2938	171754	69986	66495	35273	1107	212705	212705

Note: all regressions include age and technology field dummies. # The estimates of last column also include type of patentee dummies.
*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level,
and ****The valididty ofthe model fit is questinable.

Table A-6: Estimates of the Logit Regressions of the Decision to Sell and Expire a Patent Conditional on its Age by Type of Patentees (With Patent Category Dummies)

	Individually Owned			Corporations (Innovators)				Govt. age.****	All	All#
	All	Unassigned	Priv. inv.****	All	Small	Medium	Large			
A. Trading decision with age										
intercept	-4.9988	-4.9320	-	-4.7036	-4.8248	-4.6152	-4.9348	-	-4.7716	-6.0797
	(0.1395)	(0.1395)	-	(0.0476)	(0.0897)	(0.0698)	(0.0958)	-	(0.0450)	(0.0566)
age_year1	1.2533	1.635	-	0.7617	1.0819	0.6687	0.3968	-	0.8584	0.8381
	(0.1397)	(0.1397)	-	(0.0477)	(0.0899)	(0.0699)	(0.0955)	-	(0.0451)	(0.0451)
age_year2	0.8623	0.7733	-	0.7305	1.0121	0.6219	0.4689	-	0.7475)	0.7253
	(0.1399)	(0.1400)	-	(0.0478)	(0.0900)	(0.0700)	(0.0956)	-	(0.0452	(0.0452)
age_year3	0.6869	0.6024	-	0.6932	0.9541	0.5490	0.5276	-	0.6835	0.6592
	(0.1401)	(0.1402)	-	(0.0479)	(0.0901)	(0.0701)	(0.0956)	-	(0.0452)	(0.0452)
age_year4	0.6743	0.5853	-	0.6883	0.9461	0.5157	0.5640	-	0.6780	0.6516
	(0.1401)	(0.1403)	-	(0.0479)	(0.0902)	(0.0702)	(0.0957)	-	(0.0453)	(0.0453)
age_year5	0.8324	0.7432	-	0.6964	0.9655	0.4808	0.6529	-	0.7110	0.6948
	(0.1405)	(0.1407)	-	(0.0481)	(0.0904)	(0.0706)	(0.0959)	-	(0.0454)	(0.0454)
age_year6	0.6365	0.5527	-	0.5967	0.8694	0.3866	0.5342	-	0.5986)	0.5820
	(0.1409)	(0.1411)	-	(0.0482)	(0.0906)	(0.0709)	(0.0963)	-	(0.0456	(0.0456)
age_year7	0.5572	0.4704	-	0.5640	0.8118	0.3309	0.5726	-	0.5554	0.5382
	(0.1412)	(0.1414)	-	(0.0484)	(0.0908)	(0.0711)	(0.0965)	-	(0.0457)	(0.0457)
age_year8	0.6073	0.5240	-	0.5437	0.8038	0.2667	0.5939	-	0.5443	0.5274
	(0.1413)	(0.1415)	-	(0.0485)	(0.0910)	(0.0715)	(0.0966)	-	(0.0458)	(0.0458)
age_year9	0.7953	0.7104	-	0.6085	0.8299	0.3280	0.7427	-	0.6326	0.6228
	(0.1425)	(0.1428)	-	(0.0490)	(0.0918)	(0.0724)	(0.0972)	-	(0.0462)	(0.0462)
age_year10	0.6839	0.5940	-	0.5882	0.7445	0.4077	0.6719	-	0.5988	0.5876
	(0.1433)	(0.1437)	-	(0.0492)	(0.0923)	(0.0725)	(0.0979)	-	(0.0465)	(0.0465)
age_year11	0.6507	0.5530	-	0.5373	0.6851	0.3174	0.6833	-	0.5517	0.5396
	(0.1440)	(0.1445)	-	(0.0496)	(0.0929)	(0.0733)	(0.0984)	-	(0.0468)	(0.0468)
age_year12	0.5872	0.5214	-	0.4646	0.5993	0.2551	0.6132	-	0.4808	0.4688
	(0.1451)	(0.1455)	-	(0.0502)	(0.0939)	(0.0743)	(0.0993)	-	(0.0473)	(0.0473)
age_year13	0.8100	0.7280	-	0.5679	0.6845	0.4620	0.6003	-	0.5983	0.5914
	(0.1489)	(0.1497)	-	(0.0517)	(0.0965)	(0.0763)	(0.1028)	-	(0.0487)	(0.0488)
age_year14	0.6749	0.6166	-	0.5220	0.6916	0.2805	0.6811	-	0.5408	0.5326
	(0.1529)	(0.1538)	-	(0.0530)	(0.0982)	(0.0796)	(0.1042)	-	(0.0500)	(0.0500)
age_year15	0.5742	0.4934	-	0.3306	0.4812	0.1986*	0.3688	-	0.3629	0.3577
	(0.1578)	(0.1593)	-	(0.0556)	(0.1027)	(0.0830)	(0.1104)	-	(0.0523)	(0.0524)
age_year16	0.2423***	0.1982***	-	0.3156	0.3192	0.1556**	0.5532	-	0.3123	0.3075
	(0.1730)	(0.1743)	-	(0.0584)	(0.1098)	(0.0878)	(0.1125)	-	(0.0552)	(0.0553)
Obs	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070	12876456	12876456
B. Expiring decision										
intercept	-0.1314	-0.1270	-0.2172	-0.5601	-0.5771	-0.6523	-0.7339	0.2372	-0.3483	0.3312
	(0.0117)	(0.0121)	(0.0484)	(0.00582)	(0.00954)	(0.00961)	(0.0140)	(0.0506)	(0.00495)	(0.0124)
age_year5	-0.4045	-0.3964	-0.5712	-1.1014	-0.7795	-1.1854	-1.4110	-1.2431	-0.8935	-0.9873
	(0.0118)	(0.0121)	(0.0482)	(0.00517)	(0.00933)	(0.00841)	(0.00948)	(0.0405)	(0.00461)	(0.00470)
age_year9	-0.0199***	-0.0198***	-0.0305***	-0.3157	-0.1802	-0.3428	-0.4216	0.1537	-0.2366	-0.2785
	(0.0125)	(0.0129)	(0.0509)	(0.00522)	(0.00969)	(0.00842)	(0.00922)	(0.0415)	(0.00476)	(0.00483)
Obs	373918	352559	21359	1911564	559918	712799	638847	35882	2321364	2321364

Note: all regressions include age and technology field dummies. # The estimates of last column also include type of patentee dummies.
*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, *** Not statistically significant at the 10% level, ****The valididty of the model fit is questionable.